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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G01N 21/17

A1

(11) International Publication Number: **WO 99/44040**

(43) International Publication Date: 2 September 1999 (02.09.99)

(21) International Application Number: PCT/NO99/00065

(22) International Filing Date: 26 February 1999 (26.02.99)

(30) Priority Data:
60/076,045 26 February 1998 (26.02.98) US

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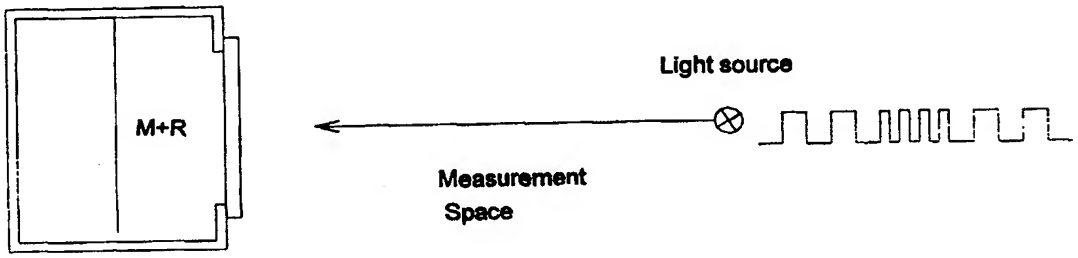
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
With amended claims.
In English translation (filed in Norwegian).

(54) Title: A METHOD FOR DRIFT COMPENSATED MEASUREMENT OF GAS CONCENTRATION, AND A PHOTOACOUSTICAL GAS SENSOR



(57) Abstract

A photoacoustical gas detector comprises at least one light source transmitting "chopped" light through a room in which a certain gas shall be detected/measured, and further a measurement cell having a window through which the light is passed. The measurement cell contains the same gas (measurement gas) as the one to be detected/measured, and a sound sensor for picking up sound generated in the gas in the cell. In order to compensate for drift due to deposits on windows or due to light source variations, one additional gas is provided inside the cell. This additional gas has an absorption spectrum that is characteristically different from the absorption spectrum of the measurement gas.

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"A METHOD FOR DRIFT COMPENSATED MEASUREMENT OF GAS CONCENTRATION, AND A PHOTOACOUSTICAL GAS SENSOR"

The present invention relates generally to measurement or detection of gas in a room, and more particularly the invention relates to a photoacoustical gas sensor and a measuring method wherein measures have been taken to compensate for drift at measurement end or in a light source.

Initially it is referred to the applicant's own previous patent application no. 1997.5447 which in principle relates to a dynamic pressure sensor, but which application also discloses a photoacoustical gas detection sensor based on such a dynamic pressure sensor. The measurement principle is that pulsed light from a light source passes through a (external) room to be investigated with regard to a certain gas, and falls toward a wavelength matched window in a wall surrounding a closed chamber. The light wavelengths match or cover the absorption line spectrum of said certain gas, so that presence of the gas in the room will influence the intensity of the light that reaches and passes through the window. The same gas that is to be detected/measured as to concentration in the "external" room, is contained also in the closed chamber. The gas in the chamber will then be heated/cooled intermittently at the same rate as the light pulses, and the chamber pressure will vary at the same rate, and to a degree that is a direct function of the concentration of the gas searched for in the "external" room. The dynamic pressure variations that arise in the gas in the chamber, can be sensed/measured by a dynamic pressure sensor.

The dynamic pressure sensor used in the above mentioned NO 1997.5447 is of a type having a diaphragm with a mechano-electric transducer. The closed chamber is preferably divided in two by the diaphragm, and a narrow restriction or opening along parts of the diaphragm edge, makes sure that the gas is in both chamber parts, and that pressure equalization is achieved for sufficiently low sound frequencies, so that frequencies can only be measured above a certain "corner frequency", the position of which depends on chamber volume, restriction size and diaphragm volume displacement.

It turns out that also the gas sensor type mentioned hereabove may experience drift, i.e. that the measurement signal that is achieved, exhibits a slow

variation over time due to e.g. collection of contamination deposits on sensitive surfaces, variation in the light source etc. The goal of the present invention is to provide a solution to the drift problem for this type of gas sensor.

From US 5,159,411 is previously known a method for investigating a gas mixture contained in a closed chamber, where another gas in the mixture masks important absorption lines of a certain gas in the mixture, which certain gas is of interest. Therefore, a third gas is added to the mixture in the chamber, to achieve so-called "kinetic" cooling. Pulsed laser light is transmitted through the chamber, which chamber has two windows and an inside microphone, and sound picked up by the microphone is measured, and the intensity of the remaining light leaving the chamber, is measured by means of a light detector. One sees that even if one further gas is added to a gas mixture to be measured, this is a measurement set-up in which no search is made for a gas in a room by means of a shut-up amount of the same gas in a special chamber. This means that the measurement problems and the measurement methodology are quite different than in the present invention. The drift problem in a sensor of the type mentioned above in connection with NO 1997.5447, cannot be solved using US 5,159,411 as a basis.

A gas sensor of somewhat more cognate type is known from US 5,616,826, which utilizes a closed chamber with another gas than the one to be measured, however with a similar absorption spectrum. This sensor is custom-designed for measuring unstable gases like e.g. ozone. However, the drift problem is not approached at all in this US patent.

In accordance with the present invention, a solution is provided to the problem that has been sketched above. In accordance with the invention there is provided a method for drift compensated detection or concentration measurement of a gas in a room, where

- light is directed from at least one light source through at least part of the room toward and through a window constituting part of a wall surrounding a closed chamber containing the same gas as the one to be detected or measured,
- the light is pulsed in order to heat the gas in the chamber intermittently by absorption or scattering of light energy, at least one of the light sources emitting light having wavelengths matching the absorption line spectrum of

the gas, and the chamber containing a diaphragm with a mechano-electric transducer for picking up sound generated by the gas through the above mentioned intermittent heating.

The method in characterized in that

- a special reference gas not expected to appear naturally in the room, and having a different absorption spectrum, however with lines in the same wavelength range as the gas to be detected or measured, is added in advance to the chamber together with the measurement gas, and that
- the light is sent into the closed chamber with two different values of at least one of the parameters spectral content, pulse frequency and phase, whereby measurement gas and reference gas will provide detectably different signal contributions from the transducer for the two different parameter values.

In accordance with the invention, there is further provided a photo-acoustical sensor for drift compensated detection of a gas or measurement of concentration of gas in a room, said gas sensor comprising at least one pulsed light source for transmitting light through at least part of the room and through a window constituting part of a wall surrounding a closed chamber containing the same gas as the one to be detected or measured, and which chamber also contains a diaphragm having a mechano-electric transducer for picking up sound generated by the contained gas when/if it is heated intermittently by absorption of light energy, the light source(s) emitting light having wavelengths covering the absorption line spectrum of the gas.

The gas sensor of the invention is characterized in that

- the chamber contains also a reference gas not expected to appear naturally in the room, and which reference gas has a different absorption spectrum, however with lines in the same wavelength range as the gas to be detected or measured, and that
- the light source(s), light path defining means and the closed chamber are arranged in such a manner that at least one of the parameters spectral content, pulse frequency and phase can be provided with two different values, in order that measurement gas and reference gas in the chamber

may provide detectably different signal contributions from the transducer for the two different parameter values.

Advantageous embodiments of the method and the photoacoustical gas sensor in accordance with the invention, appear from the appended dependent patent claims 2-7 and 9-17.

In the following, the invention shall be illuminated more closely through a mention of exemplary embodiments, and it is at the same time referred to the appended drawings, where

figs. 1a, b, c show absorption spectra for carbon dioxide gas, methanol vapor and ethanol vapor respectively;

fig. 2 shows an absorption spectrum of laughing gas N_2O, which gas can be used for reference gas;

fig. 3 shows schematically a measurement set-up that can be used in certain embodiments of the invention, using two light sources and one window in a measurement cell;

fig. 4 shows schematically an alternative set-up of apparatus that can be used in another embodiment of the invention, using two light sources directing light toward respective parts of the measurement cell through separate windows;

fig. 5 shows schematically a further embodiment in accordance with the invention, using one light source and a two-part measurement cell with separate windows; and

fig. 6 shows schematically the most preferred embodiment of the invention, in which there is used one light source and one window in the measurement cell, and wherein the light source is pulsed variably.

As mentioned above, the invention relates to photoacoustical sensors, and in particular sensors having a gas in a closed chamber together with a microphone element, i.e. the same gas that it is interesting to detect in "the surroundings". Such gas sensors will be subject to drift, in similarity with other types of gas sensors. Often some of the drift will be due to a deposit on the sensitive surfaces. One example of this, is that in a kitchen with a gas stove, where it is clearly of interest to install a gas sensor, most surfaces will little by little be covered by fatty smoke. Photoacoustical sensors will also be influenced by a deposit on the

surfaces. The signal from such photoacoustical gas sensors will also be subject to drift if the light source used, exhibits drift.

A solution to the two types of drift problem mentioned above, will be to provide a reference signal. The idea of the invention is then to fill additional gas into the chamber. This gas must have absorption lines in the same wavelength range as the gas that it is desirable to investigate. It is an important premise that the reference gas used as an additional gas in a chamber, does not appear in a natural manner in the measurement area where the sensor is mounted. In figs. 1a, b, c appear the most important absorption lines for carbon dioxide gas (CO_2), methanol vapor and ethanol vapor, respectively. In various connections it may be of importance to monitor these gases. One will note, see fig. 1a, that carbon dioxide exhibits a relatively wide peak in its absorption spectrum, in a wave number range from about 2.300 to about 2.280 to about 2.400. (Wave number defined as $2\pi/\lambda$, λ wavelength).

For methanol, see fig. 1b, one finds a sharp peak close to wave number 1.000, and a lesser peak close to wave number 3.000. For ethanol, see fig. 1c, the highest peak is found near wave number 1.000, as well as a rather distinct peak near wave number 3.000, Laughing gas, N_2O, will be a usable reference gas for all of the three gases mentioned. This is because laughing gas has a distinct peak in its absorption spectrum near wave number 2.200, and none of the gases mentioned above exhibit any peak close to wave number 2.200 in their absorption spectra. There are of course environments where laughing gas may appear, and where such a reference gas will clearly not be favorable, but it is assumed that laughing gas quite often will be a usable reference gas for the three measurement gases mentioned above.

The electronic signal processing unit that is used for processing signals from the microphone or transducer element in the measurement chamber, must in some manner be able to distinguish between the signal from the measurement gas and from the reference gas (i.e. the additional gas). In other words, it is an important point that when the light entering the measurement chamber has such characteristics as to be absorbed specially by the measurement gas, the light vibration that is picked up, e.g. with a frequency according to the flash frequency of this light, will provide a signal that is separable from the signal belonging to the

light absorbed specially by the reference gas, and which is then flashed using another frequency. E.g. signal amplitudes associated with the two flash frequencies/pitches that are picked up, may be possible to distinguish. Then, when the signal from the reference gas is independent of gas presence in the room to be investigated, since no such reference gas will ever appear in the room in a significant concentration, possible changes in the signal from the reference gas will only be due to typical drift factors. The same drift factors will influence the signal from the measurement gas, but the reference signal can then be used for drift correction.

Practical examples of arrangements that can be used, will be illuminated in the following:

In fig. 3 appears schematically a measurement cell filled with measurement gas (M) and reference gas (R). The measurement cell is in this case depicted as a two-part measurement cell wherein a diaphragm constitutes a partition dividing the cell in two chambers, while a restriction (a narrow opening) ensures that both chambers contain the same gas. In this type of arrangement it is not necessary for the invention that the measurement cell is divided in two, in principle it would be sufficient with only one chamber having a transducer element (or microphone) of some type therein.

Light is transmitted toward the chamber window through the room to be measured/investigated regarding the measurement gas, from two separate light sources. The light sources are provided with respective, specially adapted filters, and both light sources are flashed by switching on/off (i.e. pulsing of the light source itself), or by "chopping" using an electro-optical or mechanical chopper.

The filters are specially matched in order to absorb just those absorption lines that are of interest for the measurement gas and the reference gas, respectively, and the filters may then e.g. be constituted by light transmission cells containing just one respective of the two gases in question. The light from the light source having an M filter (i.e. a filter containing the measurement gas or a filter having corresponding absorption lines) can then only measure R gas, and light from the light source having an R filter, is only able to measure M gas. Disregarding drift factors, this means that light from the light source with the M filter will constantly give rise to a constant R signal, since R gas will never appear in the

room, which means a constant R gas state (=0) in the room, and the R gas amount in the measurement cell will be constant.

Contrary thereto (still when disregarding drift factors), the light from the source with an R filter will be able to respond (in an ordinary manner) to variable occurrence of M gas in the room, i.e. it will be attenuated according to the amount of M gas, and the light reaching the measurement cell will then be attenuated just at those wavelengths where the M gas inside the cell is able to absorb it. Less light will then be absorbed by the M gas inside the cell, i.e. a weaker sound signal will be produced at the frequency in question.

As previously mentioned, the two light sources are preferably flashed with different frequencies. In the case just described, two characteristic sound frequencies or pitches can be listened to inside the measurement cell, one pitch will stay at a constant intensity, whereas the other will be subject to intensity variation in an inverse relation to the amount of measurement gas (measurement gas concentration) in the room outside the cell. Correction with respect to drift can now be made by means of the inherently constant R signal, which signal will only exhibit a slow variation due to drift. The correction may be of subjective or relative type, depending on the signal nature.

The flashing series of the two lamps can be run simultaneously, since the two different flash frequencies nevertheless provide characteristic and separate pitches inside the measurement cell simultaneously, which pitches can be distinguished through signal processing that there is no need to illuminate further here. However, it is also possible to alternate between the two light sources, so that pulse trains are sent in an alternating manner.

In the set-up shown in fig. 3, the two light sources must not necessarily flash at different frequencies. One and the same frequency may also be used, but the flashing must then be made in such a manner that the two light pulse trains are in mutually opposite phases. When such opposite phase flashing is used, and when none of the gases are present in the room, both pressure signals may possibly be equal in the measurement cell, i.e. the sensor unit will hardly detect any noticeable vibration at all, since both halves of a period will give the same amplitude. But when the gas searched for, appears, an imbalance will appear

between the two period halves, which imbalance will give a clearly detectable difference.

The chopping/flashing is typically executed using frequencies in the range from about 1 Hz to about 10 kHz.

Another measurement arrangement is shown schematically in fig. 4, where the measurement cell is divided in two chambers by means of a diaphragm having a restriction, so that the same gases are present in both chambers. Additionally, the diaphragm has a mechano-electric transducer able to deliver electric signals in accordance with the movements of the diaphragm. Each respective chamber has a window, and the two light sources are arranged in such a manner that they transmit light to respective chambers in the measurement cell. For the rest, the same technique is used as in the embodiment shown in fig. 3, with adapted M and R filters together with the light sources. Both light paths toward the measurement cell pass through the room to be investigated/measured. (To ensure this, the two light sources may possibly be arranged close to each other, and transmit light beams rather close to each other, toward a not shown receiver unit that guides the light beams to the respective measurement cell windows by means of mirrors or possibly fiber optics.)

In this case the two light sources can be flashed at the same frequency and in phase with each other, or two different frequencies can be used. Also in this case, i.e. in the case with same frequency and phase for light toward the two chambers, it is so that a good resultant signal is achieved when an imbalance arises between the two pressure signals toward the diaphragm from two sides, when the measurement gas starts to appear in the measurement room, while when no measurement gas is present, a balance can be set up with equally strong pressure signals from both sides, i.e. a very low output signal from the sensor due to such a balance.

It has been presupposed that the restriction and the diaphragm give the opportunity for measuring sufficiently low frequencies, i.e. that the chopping frequency/frequencies lie above the corner frequency of the diaphragm.

When different frequencies are used, detectable signals having correspondingly different frequencies will be measurable by themselves, i.e. the diaphragm will respond to pressure frequencies from both sides.

An advantage of using the same frequency, is, as explained above, that there will be a small signal when there is no gas in the measurement room between light sources and measurement cell, while the signal will grow significantly when there is a rise in the concentration of the gas searched for.

However, it is to be noted that as long as two light sources are used, there will still be sensitivity to drift in the very light sources. But, since as mentioned above, it is possible to use two light sources flashing in phase with each other, it is obviously possible to use only one single flashing light source, together with an arrangement of mirrors or e.g. fiber optics. Then, two light paths must be defined out from the same light source, M and R filters must be placed in respective light paths, and the light must be sent toward the measurement cell from two sides (mostly such as shown in fig. 4), see fig. 5, which shows such an arrangement with only one light source, schematically. In this case the set-up is also rather similar to the arrangement shown in fig. 4, and the operation is analogous to the "same frequency and phase" version mentioned above.

However, it is not very practical to have light enter from two sides toward the measurement cell, and the use of mirrors will also complicate the system to a certain degree. It is further a clear premise for these methods, that all surfaces are contaminated to approximately the same degree.

Referring to fig. 6, finally a seemingly promising method shall be mentioned, which method is assumed to be the preferred method. In this case the distinction between the signal from the two gases (M, R) is made by utilizing the fact that the gases have different relaxation times. A light source of the same type as previously mentioned, can be used, the light path will be simple, from the flashing light source through the room where the gas of interest shall be detected, and direct to the measurement cell, and a filter is not necessary. A microcontroller (not shown) controls the light frequency, and now and then it will change into another frequency than the normal frequency, in order to provide a reference signal. The two frequencies that are used, are adapted to the relaxation times of the two gases, i.e. the relaxation times associated with light excitation of certain excitation modi for the gas molecules. If e.g. CO_2 is the measurement gas, one such relaxation time of interest, is known to be about 8 μs. Laughing gas (N_2O) may, as previously mentioned, be an interesting reference gas in connection with CO_2, and

a corresponding relaxation time for N_2O is about 0,8 μs, which is lower by a factor of 10. The two pulse frequencies selected may then typically exhibit the same ratio, i.e. one frequency may be selected ten times as high as the other one. Pulse frequencies of interest are generally situated preferably in the range of about 10 Hz to a few kilohertz, and the actual frequencies that are used, will depend on the dimensions and the gas pressure in the measurement cell. The different relaxation times of the measurement gas and the reference gas will then cause different ratios between the signals from the two flash frequencies.

This preferred method will be reasonable with regard to costs, and at the same time it will provide a possibility for letting a sensor calibrate itself, i.e. make an automatic resetting when information is submitted, e.g. by using a push button, to the effect that the measurement gas concentration is zero in the measurement room. Thereby, all drift can be compensated for completely. The sensor will also be able to tell when it has become so dirty that it cannot be used any more (self test). This means that when the reference gas signal becomes very weak due to e.g. fouling, a special signal is produced which means that cleaning must be undertaken.

PATENT CLAIMS

1. A method for drift compensated detection or concentration measurement of a gas in a room, where

- light is directed from at least one light source through at least part of the room toward and through a window which constitutes part of a wall surrounding a closed chamber containing the same gas as the gas to be detected or measured,
- the light is pulsed in order to heat the gas in the chamber intermittently by absorption or scattering of light energy, at least one of said light sources emitting light having wavelengths matching the absorption line spectrum of said gas, and said chamber containing a diaphragm with a mechano-electric transducer for picking up sound generated by the gas through said intermittent heating,

characterized in that

- a special reference gas not expected to appear naturally in said room, and having a different absorption spectrum, however with lines in the same wavelength range as the gas to be detected or measured, is added in advance in the chamber together with the measurement gas, and that
- the light is transmitted into the closed chamber with two different values of at least one of the parameters spectral content, pulse frequency and phase, whereby measurement gas and reference gas will provide detectably different signal contributions from said transducer for the two different parameter values.

2. The method of claim 1,

characterized in that one single light source is used, which light source is pulsed in a main pulse train having a main frequency, intermittently interrupted, in accordance with a predetermined program, by a reference pulse train having a reference frequency that is different from the main frequency, said two pulse frequencies being selected in relation to the relaxation times of the two gases associated with light excitation of certain excitation modi for the gas molecules,

whereby the different relaxation times of the two gases cause a different ratio between the signals from the two gases at said two pulse frequencies.

with absorption spectrum matching the reference gas, and that the two light sources are pulsed with different frequencies.

6. The method of claim 1,
characterized in that two separate light sources are utilized, said light sources directing light through the room toward the chamber window, each light source having a filter toward the light path, one with an absorption spectrum matching the measurement gas and the other with absorption spectrum matching the reference gas, and that the two light sources are pulsed with different pulse frequencies or with the same frequency but in mutually opposite phase.

7. The method of claim 1,
characterized in that one single light source is utilized, said light source being able to emit light having a variable or tunable spectral content, the spectral content of said light source being alternately matched to the absorption spectra of the measurement gas and the reference gas.

8. A photoacoustical gas sensor for drift compensated detection of a gas or measurement of concentration of a gas in a room, said gas sensor comprising at least one pulsed light source for transmitting light through at least part of the room and through a window constituting part of a wall surrounding a closed chamber which contains the same gas as the gas to be detected or measured, which chamber also contains a diaphragm with a mechano-electric transducer for picking up sound generated by the contained gas when/if it is heated intermittently by absorption of light energy, said light source(s) emitting light with wave lengths matching the absorption line spectrum of the gas,
characterized in that

- the chamber contains also a reference gas not expected to appear naturally in the room, and having a different absorption spectrum, however with lines

in the same wavelength length as the gas to be detected or measured, and that

- the light source(s), light path defining means and the closed chamber are arranged in such a manner that at least one of the parameters spectral content, pulse frequency and phase can be given two different values, in order that the measurement gas and the reference gas inside the chamber shall be able to provide detectably different signal contributions from the transducer for the two different parameter values.

9. The photoacoustical gas sensor of claim 8, characterized in that it comprises one single light source arranged so that it can be pulsed with at least two different frequencies selected in relation to the relaxation times of the two gases associated with light excitation of certain excitation modi of the gas molecules.

10. The gas sensor of claim 9, characterized in that the light source comprises a mechanical or electro-optical chopper.

11. The gas sensor of claim 9, characterized in that the light emitting element of the light source can be pulsed directly.

12. The photoacoustical gas sensor of claim 8, wherein the closed chamber is divided in two chambers by said diaphragm, which diaphragm has a restriction so that the same gas content resides in both chamber parts, and wherein both chamber parts have a window, characterized in that the gas sensor comprises one single light source for emitting light along two separate paths, said light source comprising respective filters for each path, one filter with an absorption spectrum matching the measurement gas, and the other with an absorption spectrum matching the reference gas, and the light path defining means comprising mirror devices close to the chamber in order to direct the light of the two paths against the two windows of the chamber

after passage through the room, the light source being arranged to be pulsed at one single frequency.

13. The photoacoustical gas sensor of claim 8, wherein the closed chamber is divided in two chambers by the diaphragm, which diaphragm has a restriction so that both chamber parts have the same gas content, and wherein both chamber parts have a window,
characterized in that the gas sensor comprises two light sources arranged to direct light through the room against respective chamber windows, and that each light source has a filter toward the light path, one with an absorption spectrum matching the measurement gas, and the other with an absorption spectrum matching the reference gas.

14. The photoacoustical gas sensor of claim 8,
characterized in that it comprises two separate light sources arranged to direct light through the room toward the chamber window, each light source having a filter toward the light path, one with an absorption spectrum matching the measurement gas, and the other one with an absorption spectrum matching the reference gas, the two light sources being adapted to be pulsed at different pulse frequencies, or at the same frequency, but in mutually opposite phase.

15. The gas sensor of claim 12, 13 or 14,
characterized in that the filters are constituted by chambers filled with the respective gases and having windows for light transmission.

16. The photoacoustical gas sensor of claim 8,
characterized in that it comprises one single light source adapted to emit light having a variable or tunable spectral content, so that the spectral content of the light source can be alternately matched to the absorption spectra of the measurement gas and the reference gas.

17. The gas sensor of claim 16,
characterized in that the light source comprises a tunable filter toward the light path, e.g. a Fabry-Perot resonator.

AMENDED CLAIMS

[received by the International Bureau on 14 July 1999 (14.07.99);
new claims 3, 4 and 5 added; remaining claims unchanged (6 pages)]

1. A method for drift compensated detection or concentration measurement of a gas in a room, where

- light is directed from at least one light source through at least part of the room toward and through a window which constitutes part of a wall surrounding a closed chamber containing the same gas as the gas to be detected or measured,
- the light is pulsed in order to heat the gas in the chamber intermittently by absorption or scattering of light energy, at least one of said light sources emitting light having wavelengths matching the absorption line spectrum of said gas, and said chamber containing a diaphragm with a mechano-electric transducer for picking up sound generated by the gas through said intermittent heating,

characterized in that

- a special reference gas not expected to appear naturally in said room, and having a different absorption spectrum, however with lines in the same wavelength range as the gas to be detected or measured, is added in advance in the chamber together with the measurement gas, and that
- the light is transmitted into the closed chamber with two different values of at least one of the parameters spectral content, pulse frequency and phase, whereby measurement gas and reference gas will provide detectably different signal contributions from said transducer for the two different parameter values.

2. The method of claim 1,

characterized in that one single light source is used, which light source is pulsed in a main pulse train having a main frequency, intermittently interrupted, in accordance with a predetermined program, by a reference pulse train having a reference frequency that is different from the main frequency, said two pulse frequencies being selected in relation to the relaxation times of the two gases associated with light excitation of certain excitation modi for the gas molecules, whereby the different relaxation times of the two gases cause a different ratio between the signals from the two gases at said two pulse frequencies.

3. The method of claim 1, wherein the closed chamber is divided in two parts by the diaphragm, which diaphragm has a restriction so that the same gas content is inside both chamber parts, and wherein both chamber parts have a window, characterized in that one single light source is utilized, said light source being allowed to emit light signals along two separate paths, said light source comprising one respective filter for each path, one having an absorption spectrum matching the measurement gas, and the other having an absorption spectrum matching the reference gas, the paths further comprising mirror devices close to the chamber in order to direct the light in the two paths against the two windows of the chamber after passage through the room, and that the light is pulsed at only one pulse frequency, whereby the gas quantities inside the two chamber parts contribute to a signal that is small when there is no measurement gas in the room, and which signal grows rapidly as a function of measurement gas concentration in said room.

4. The method of claim 1, wherein the closed chamber is divided in two chambers by the diaphragm, which diaphragm has a restriction so that both chamber parts have the same gas content, and wherein both chamber parts have a window,
characterized in that two light sources are utilized, which two light sources direct light through the room toward respective chamber windows, each light source having a filter toward the light path, one having an absorption spectrum matching the measurement gas, and the other one having an absorption spectrum matching the reference gas, and that the two light sources are pulsed at the same frequency and in phase with each other, whereby the gas quantities inside the two chamber parts contribute to a signal that is small when there is no measurement gas in the room, and which signal grows rapidly as a function of the measurement gas concentration in said room.

5. The method of claim 1, wherein the closed chamber is divided in two chambers by the diaphragm, which diaphragm has a restriction so that both chamber parts have the same gas content, and wherein both chamber parts have a window,

characterized in that two light sources are utilized, which light sources direct light through the room toward respective chamber windows, each light source having a filter toward the light path, one with an absorption spectrum adapted to the measurement gas, and the other one with absorption spectrum matching the reference gas, and that the two light sources are pulsed with different frequencies.

6. The method of claim 1,
characterized in that two separate light sources are utilized, said light sources directing light through the room toward the chamber window, each light source having a filter toward the light path, one with an absorption spectrum matching the measurement gas and the other with absorption spectrum matching the reference gas, and that the two light sources are pulsed with different pulse frequencies or with the same frequency but in mutually opposite phase.

7. The method of claim 1,
characterized in that one single light source is utilized, said light source being able to emit light having a variable or tunable spectral content, the spectral content of said light source being alternately matched to the absorption spectra of the measurement gas and the reference gas.

8. A photoacoustical gas sensor for drift compensated detection of a gas or measurement of concentration of a gas in a room, said gas sensor comprising at least one pulsed light source for transmitting light through at least part of the room and through a window constituting part of a wall surrounding a closed chamber which contains the same gas as the gas to be detected or measured, which chamber also contains a diaphragm with a mechano-electric transducer for picking up sound generated by the contained gas when/if it is heated intermittently by absorption of light energy, said light source(s) emitting light with wave lengths matching the absorption line spectrum of the gas,
characterized in that

- the chamber contains also a reference gas not expected to appear naturally in the room, and having a different absorption spectrum, however with lines

in the same wavelength length as the gas to be detected or measured, and that

- the light source(s), light path defining means and the closed chamber are arranged in such a manner that at least one of the parameters spectral content, pulse frequency and phase can be given two different values, in order that the measurement gas and the reference gas inside the chamber shall be able to provide detectably different signal contributions from the transducer for the two different parameter values.

9. The photoacoustical gas sensor of claim 8,
characterized in that it comprises one single light source arranged so that it can be pulsed with at least two different frequencies selected in relation to the relaxation times of the two gases associated with light excitation of certain excitation modi of the gas molecules.

10. The gas sensor of claim 9,
characterized in that the light source comprises a mechanical or electro-optical chopper.

11. The gas sensor of claim 9,
characterized in that the light emitting element of the light source can be pulsed directly.

12. The photoacoustical gas sensor of claim 8, wherein the closed chamber is divided in two chambers by said diaphragm, which diaphragm has a restriction so that the same gas content resides in both chamber parts, and wherein both chamber parts have a window,
characterized in that the gas sensor comprises one single light source for emitting light along two separate paths, said light source comprising respective filters for each path, one filter with an absorption spectrum matching the measurement gas, and the other with an absorption spectrum matching the reference gas, and the light path defining means comprising mirror devices close to the chamber in order to direct the light of the two paths against the two windows of the chamber

after passage through the room, the light source being arranged to be pulsed at one single frequency.

13. The photoacoustical gas sensor of claim 8, wherein the closed chamber is divided in two chambers by the diaphragm, which diaphragm has a restriction so that both chamber parts have the same gas content, and wherein both chamber parts have a window,
characterized in that the gas sensor comprises two light sources arranged to direct light through the room against respective chamber windows, and that each light source has a filter toward the light path, one with an absorption spectrum matching the measurement gas, and the other with an absorption spectrum matching the reference gas.

14. The photoacoustical gas sensor of claim 8,
characterized in that it comprises two separate light sources arranged to direct light through the room toward the chamber window, each light source having a filter toward the light path, one with an absorption spectrum matching the measurement gas, and the other one with an absorption spectrum matching the reference gas, the two light sources being adapted to be pulsed at different pulse frequencies, or at the same frequency, but in mutually opposite phase.

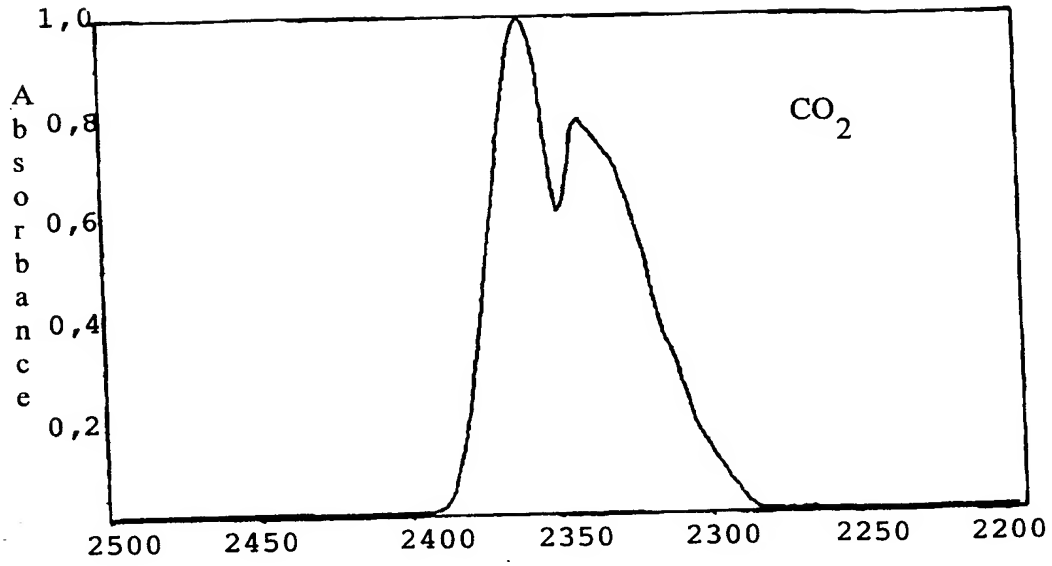
15. The gas sensor of claim 12, 13 or 14,
characterized in that the filters are constituted by chambers filled with the respective gases and having windows for light transmission.

16. The photoacoustical gas sensor of claim 8,
characterized in that it comprises one single light source adapted to emit light having a variable or tunable spectral content, so that the spectral content of the light source can be alternately matched to the absorption spectra of the measurement gas and the reference gas.

17. The gas sensor of claim 16,

characterized in that the light source comprises a tunable filter toward the light path, e.g. a Fabry-Perot resonator.

Fig. 1a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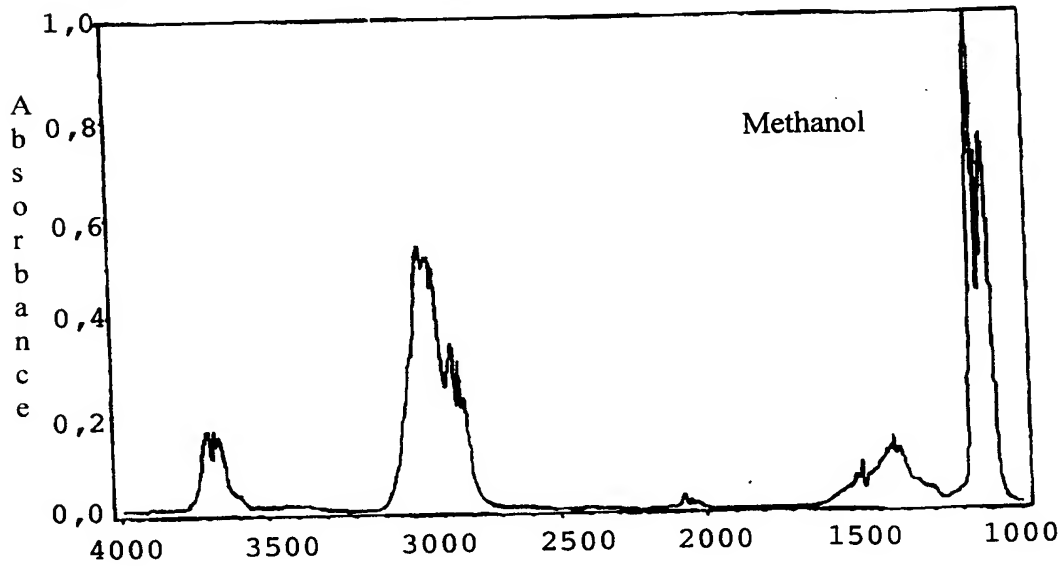
Absorbance
CO_2
2500
2450
2400
2350
2300
2250
2200
Wavenumbers

Fig. 1b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0,0
Absorbance
Methanol
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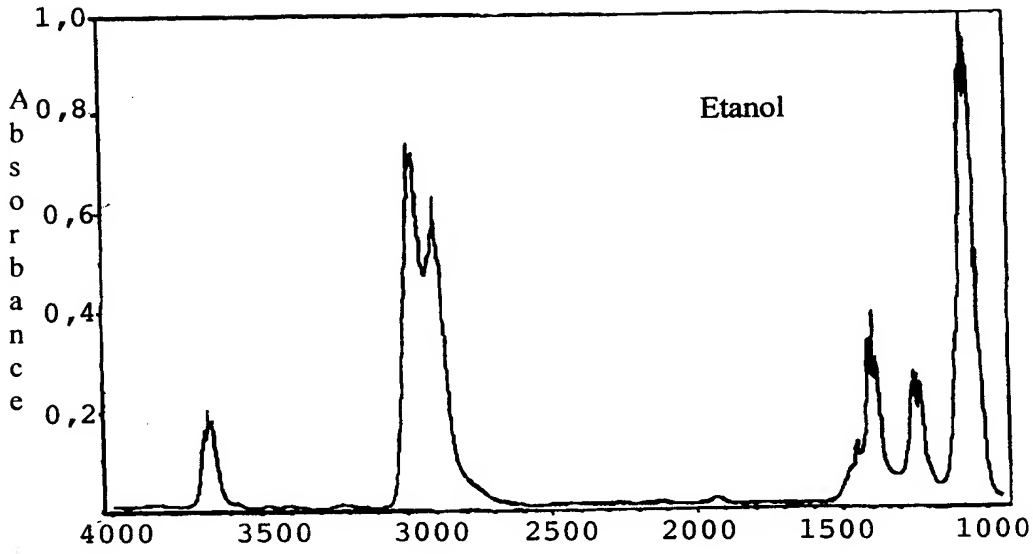
3500
3000
2500
2000
1500
1000
Wavenumbers

Fig. 1c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0,2
Absorbance
Etanol
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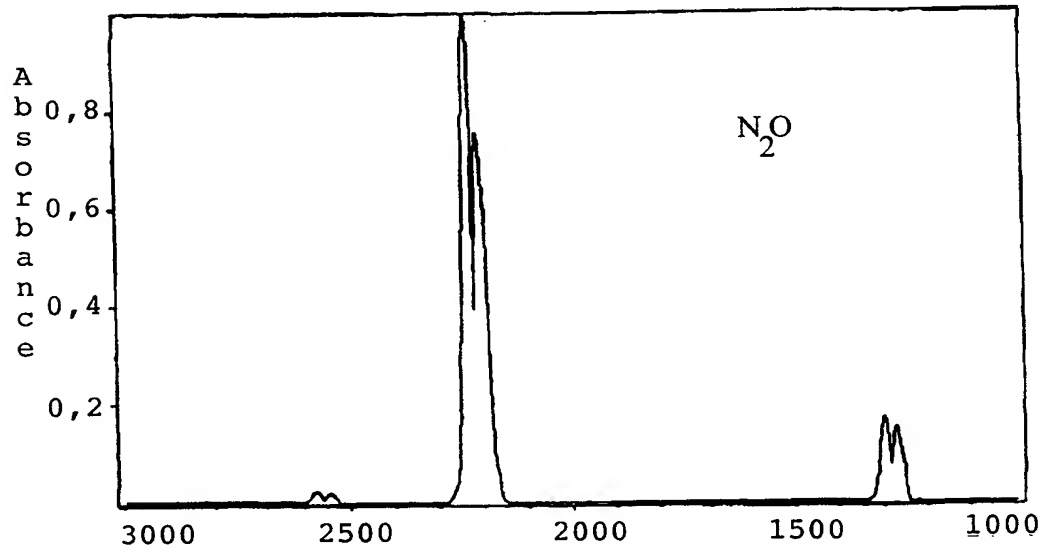
3500
3000
2500
2000
1500
1000
Wavenumbers

Fig. 2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Absorbance
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3000
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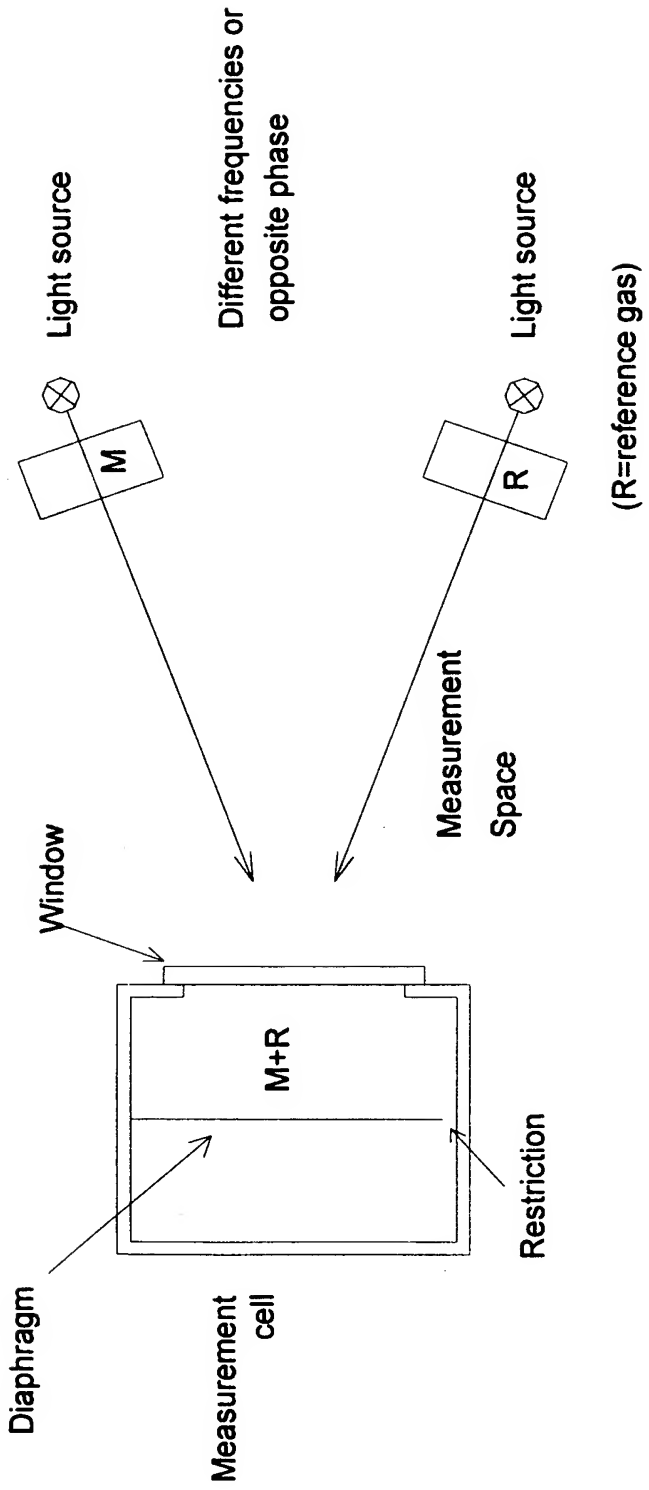
2000
1500
1000
Wavenumbers

Fig. 3


Chamber filled with gas (M=measurement gas)
which absorbs line spectrum
Light source
M
Different frequencies or
opposite phase
Light source
R
(R=reference gas)
Measurement
Space
Window
M+R
Diaphragm
Measurement
cell
Restriction

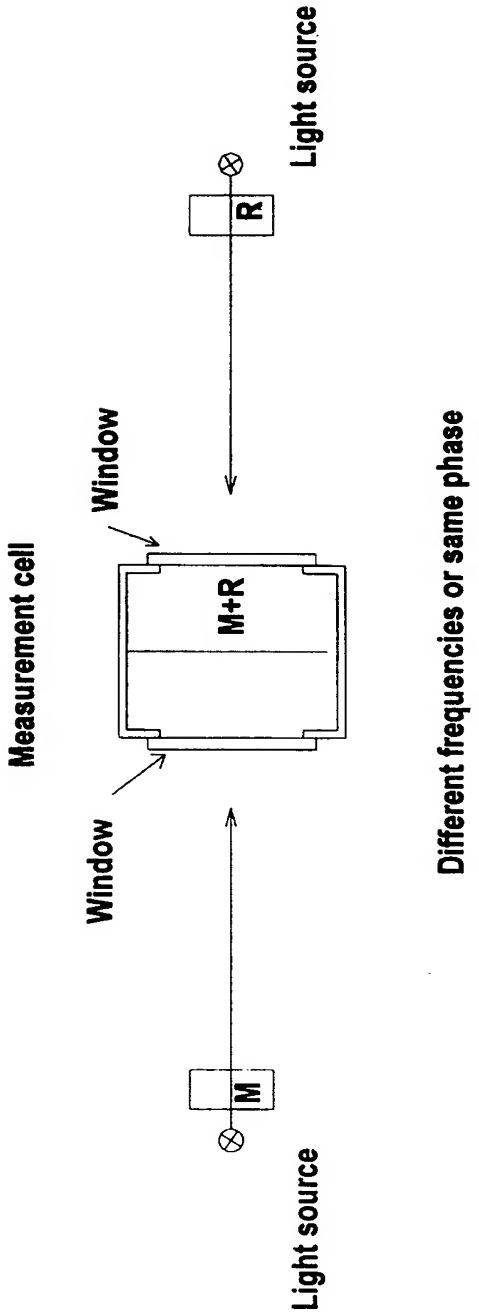

Light source
R
Window
Measurement cell
M+R
Window
Different frequencies or same phase
M
Light source

Fig. 4

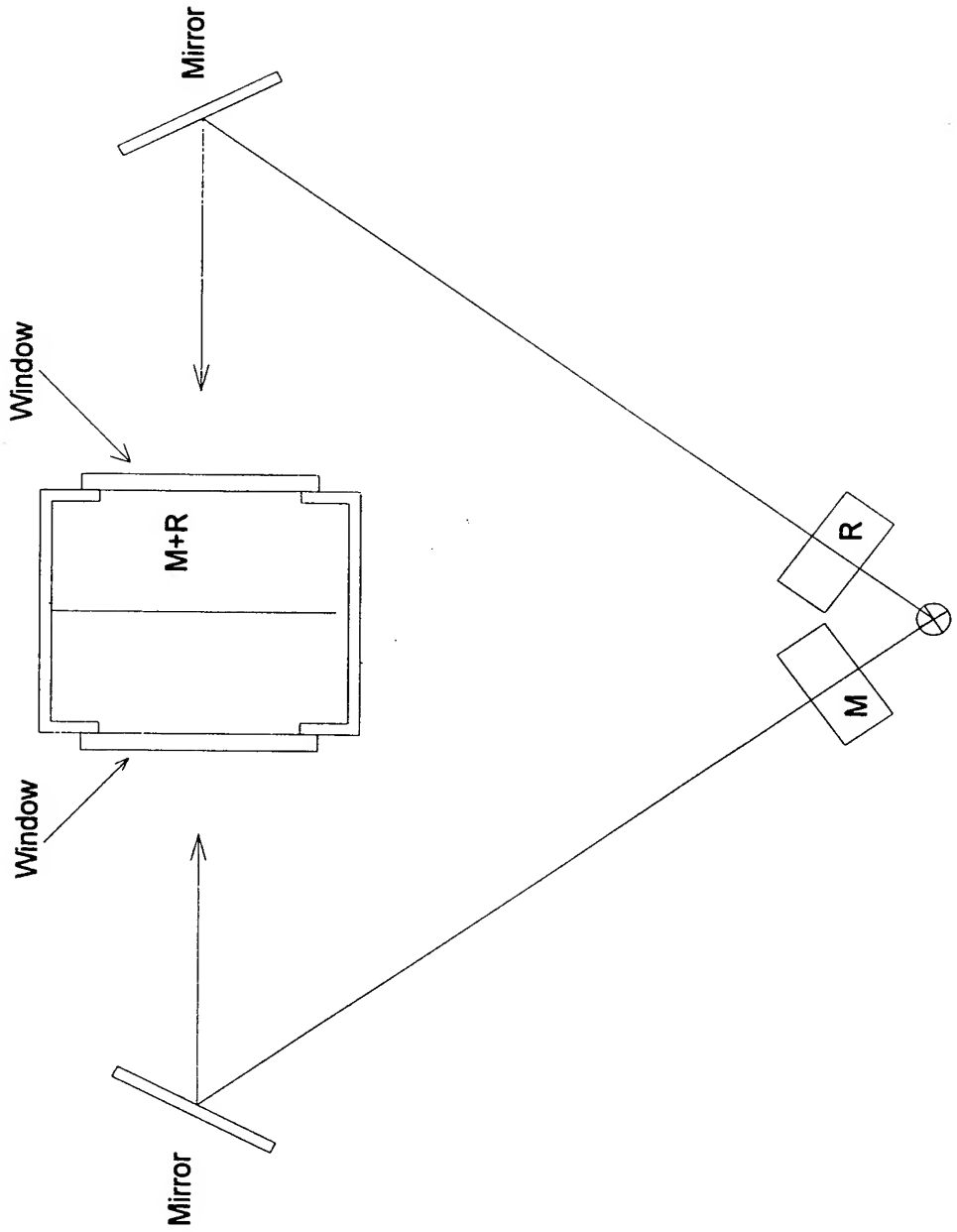


Fig. 5

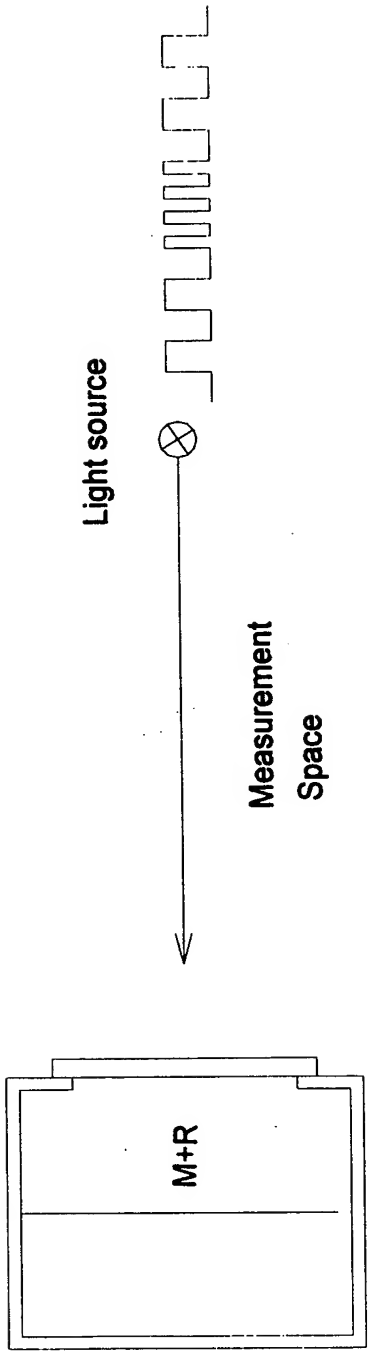


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00065

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01N 21/17
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC, WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9631765 A1 (NYFOTEK A/S), 10 October 1996 (10.10.96) --	1-17
P,A	WO 9829733 A1 (HONEYWELL INC.), 9 July 1998 (09.07.98) --	1-17
A	EP 0685728 A1 (ORBISPHERE LABORATORIES NEUCHATEL SA), 6 December 1995 (06.12.95) -- --------	1-17

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 June 1999	16 -06- 1999
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Jan Carlerud/ELY Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

03/05/99

International application No.
PCT/NO 99/00065

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9631765 A1	10/10/96	AU 5348796 A	23/10/96
		EP 0819243 A	21/01/98
		NO 300346 B	12/05/97
		NO 951334 A	07/10/96
WO 9829733 A1	09/07/98	NONE	
EP 0685728 A1	06/12/95	JP 7333139 A	22/12/95
		US 5616826 A	01/04/97

PUB-NO: WO009944040A1

DOCUMENT-IDENTIFIER: WO 9944040 A1

TITLE: A METHOD FOR DRIFT COMPENSATED MEASUREMENT OF GAS CONCENTRATION, AND A PHOTOACOUSTICAL GAS SENSOR

PUBN-DATE: September 2, 1999

INVENTOR-INFORMATION:

NAME	COUNTRY
SEEBERG, BJOERN ERIK	NO
NESE, MARTIN	NO

ASSIGNEE-INFORMATION:

NAME	COUNTRY
PRESENS AS	NO
SEEBERG BJOERN ERIK	NO
NESE MARTIN	NO

APPL-NO: NO09900065

APPL-DATE: February 26, 1999

PRIORITY-DATA: US07604598P (February 26, 1998)

INT-CL (IPC): G01N021/17

EUR-CL (EPC): G01N021/17

ABSTRACT:

CHG DATE=19991002 STATUS=O>A photoacoustical gas detector comprises at least one light source transmitting "chopped" light through a room in which a certain gas shall be detected/measured, and further a measurement cell having a window through which the light is passed. The measurement cell contains the same gas (measurement gas) as the one to be detected/measured, and a sound sensor for picking up sound generated in the gas in the cell. In order to compensate for drift due to deposits on windows or due to light source variations, one additional gas is provided inside the cell. This additional gas has an absorption spectrum that is characteristically different from the absorption spectrum of the measurement gas.